

1. A method for producing a thin film comprising:

disposing a precursor solution onto a substrate to form a precursor film, the precursor solution comprising:

precursor components to a rare earth-alkaline earth metal-transition metal oxide

5 comprising a salt of a rare earth element, a salt of an alkaline earth metal, and a salt of a transition metal in one or more solvents, wherein at least one of the salts is a fluoride-containing salt, and

a dopant component comprising a metal compound having a dopant metal capable of replacing one or more of the rare earth and alkaline earth metal of the rare-earth/alkaline-earth-

10 metal/transition metal oxide; and

treating the precursor film to form an intermediate metal oxyfluoride film including the rare earth, the alkaline earth metal, the transition metal and the dopant metal of the precursor solution.

2. The method of claim 1, wherein the dopant component comprises sufficient dopant metal  
15 to replace up to 50 atomic percent of one or more of the rare earth and alkaline earth metal of the rare-earth/alkaline-earth-metal/transition metal oxide.

3. The method of claim 1, wherein the dopant component comprises sufficient dopant metal to replace about 10 atomic % to about 30 atomic % of one or more rare earth and alkaline earth metal of the rare earth/alkaline earth and metal/transition metal oxide.

20 4. The method of claim 1, wherein the dopant component comprises sufficient dopant metal to replace about 1 atomic % to about 10 atomic % of one or more rare earth and alkaline earth metal of the rare earth/alkaline earth and metal/transition metal oxide.

5. The method of claim 1, wherein the dopant component comprises sufficient dopant metal to replace less than about 1 atomic % of one or more rare earth and alkaline earth metal of the rare earth/alkaline earth and metal/transition metal oxide.

6. The method of claim 1, wherein treating the precursor film comprises comprising heating the film at a temperature in the range of about 190°C to about 650°C to decompose the precursor and dopant components of the precursor solution.

7. The method of claim 1, wherein treating the precursor film comprises comprising heating the film at a temperature in the range of about 190°C to about 400°C to decompose the precursor and dopant components of the precursor solution.

8. The method of claim 1, further comprising:

heating the intermediate film to form an oxide superconductor, wherein the oxide superconductor comprises the dopant metal, and said oxide superconductor contains one or more defects that serve as pinning centers.

9. The method of claim 4, wherein the oxide superconductor comprises sufficient dopant metal to replace up to 50 atomic percent of one or more of the rare earth and alkaline earth metal of the oxide superconductor.

10. The method of claim 6, wherein heating the intermediate film comprises heating at a temperature in the range of about 700°C to about 825°C in a flowing gas environment having a total pressure of about 0.1 Torr to about 760 Torr and containing about 0.09 Torr to about 50 Torr oxygen and about 0.01 Torr to about 150 Torr water vapor and an inert gas with a pressure of about 0 Torr to about 750 Torr.

11. The method of claim 6, wherein heating the intermediate film comprises heating at a temperature in the range of about 700°C to about 825°C in a flowing gas environment having a total pressure of about 0.15 Torr to about 5 Torr and containing about 0.1 Torr to about 1 Torr oxygen and about 0.05 Torr to about 4 Torr water vapor.
- 5 12. The method of claim 10, wherein the film is heated to the heating temperature at a temperature ramp of about greater than 25°C per minute.
13. The method of claim 10, wherein the film is heated to the heating temperature at a temperature ramp of about greater than 100°C per minute.
14. The method of claim 10, wherein the film is heated to the heating temperature at a  
10 temperature ramp of about greater than 200°C per minute.
15. The method of claim 11, wherein the film is heated to the heating temperature at a temperature ramp of about greater than 25°C per minute.
16. The method of claim 11, wherein the film is heated to the heating temperature at a temperature ramp of about greater than 100°C per minute.
- 15 17. The method of claim 11, wherein the film is heated to the heating temperature at a temperature ramp of about greater than 200°C per minute.
18. The method of claim 6, wherein:  
the oxide superconductor is disposed on a surface of a substrate, the substrate being  
biaxially oriented;  
20 the oxide superconductor is biaxially oriented;

the oxide superconductor has a c-axis orientation that is substantially constant across its width, the c-axis orientation of the oxide superconductor being substantially perpendicular to the surface of the substrate.

19. The method of claim 1, wherein the precursor solution further comprises an additive  
5 component comprising one or more metal compounds capable of forming a second phase nanoparticle, either alone or in combination with one or more precursor salts of the rare earth element, alkaline earth metal or transition metal.

20. The method of claim 19, further comprising:

heating the intermediate film to form a rare earth-alkaline earth metal-transition metal  
10 oxide superconductor, the oxide superconductor comprising the dopant metal, wherein the oxide superconductor comprises a one or more second phase nanoparticles that serve as pinning centers.

21. A method for producing a thin film comprising:

disposing a precursor solution onto a substrate to form a precursor film, the precursor  
15 solution comprising:

precursor components to a rare earth-alkaline earth metal-transition metal oxide  
comprising a salt of a rare earth element, a salt of an alkaline earth metal, and a salt of a  
transition metal in one or more solvents, wherein at least one of the salts is a fluoride-containing  
salt, and

20 an additive component comprising one or more metal compounds capable of forming a second phase nanoparticle, either alone or in combination with one or more of the precursor components of the precursor solution; and

treating the precursor film to form an intermediate metal oxyfluoride film including the rare earth, the alkaline earth metal, the transition metal and the additive metal of the precursor solution.

22. The method of claim 21, wherein the additive component comprises up to 0.5 - 20 atomic percent of the metals making up the precursor solution.

23. The method of claim 21, wherein the additive component is in an amount sufficient to form a film having nanoparticles in a density of about 20 to about 10,000 particles/ $\mu\text{m}^3$ .

24. The method of claim 21, wherein the additive component is in an amount sufficient to form a film having nanoparticles in a density of about 100 to about 10,000 particles/ $\mu\text{m}^3$ .

25. The method of claim 21, wherein the additive component is in an amount sufficient to form a film having nanoparticles in a density of about 1,000 to about 10,000 particles/ $\mu\text{m}^3$ .

26. The method of claim 21, wherein the additive component is in an amount sufficient to form a film having nanoparticles in a density of greater than about 1,000 particles/ $\mu\text{m}^3$ .

27. The method of claim 21, wherein treating the precursor film comprises heating the film at a temperature in the range of about 190°C to about 650°C to decompose the precursor and additive components of the precursor solution.

28. The method of claim 21, further comprising:

heating the intermediate film to form a rare earth-alkaline earth metal-transition metal oxide superconductor and one or more second phase nanoparticles, the secondary phase nanoparticle located within a grain of the oxide superconductor and serving as particulate pinning center.

29. The method of claim 28, wherein the nanoparticle has a maximum dimension of 1-100 nm.

30. The method of claim 28, wherein heating the intermediate film comprises heating at a temperature in the range of about 700°C to about 825°C in a flowing gas environment having a  
5 total pressure of about 0.1 Torr to about 760 Torr and containing about 0.09 Torr to about 50 Torr oxygen and about 0.01 Torr to about 150 Torr water vapor and an inert gas with a pressure of about 0 Torr to about 750 Torr.

31. The method of claim 28, wherein heating the intermediate film comprises heating at a temperature in the range of about 700°C to about 825°C in a flowing gas environment having a  
10 total pressure of about 0.15 Torr to about 5 Torr and containing about 0.1 Torr to about 1 Torr oxygen and about 0.05 Torr to about 4 Torr water vapor.

32. The method of claim 30, wherein the film is heated to the heating temperature at a temperature ramp of about greater than 25°C per minute.

33. The method of claim 30, wherein the film is heated to the heating temperature at a  
15 temperature ramp of about greater than 100°C per minute.

34. The method of claim 30, wherein the film is heated to the heating temperature at a temperature ramp of about greater than 200°C per minute.

35. The method of claim 31, wherein the film is heated to the heating temperature at a temperature ramp of about greater than 25°C per minute.

20 36. The method of claim 31, wherein the film is heated to the heating temperature at a temperature ramp of about greater than 100°C per minute.

37. The method of claim 31, wherein the film is heated to the heating temperature at a temperature ramp of about greater than 200°C per minute.

38. The method of claim 28, wherein:

the oxide superconductor is disposed on a surface of a substrate, the substrate being

5 biaxially oriented;

the oxide superconductor is biaxially oriented;

the oxide superconductor has a c-axis orientation that is substantially constant across its width, the c-axis orientation of the superconductor being substantially perpendicular to the surface of the substrate.

10 39. The method of claim 21, wherein the additive component comprises a dispersion of nanoparticles comprising one or more metal compounds capable of forming a second phase nanoparticle, either alone or in combination with one or more precursor salts of the rare earth element, alkaline earth metal or transition metal.

40. The method of claim 21, wherein the additive component comprises one or more metal  
15 salts capable of forming a second phase nanoparticle, either alone or in combination with one or more precursor salts of the rare earth element, alkaline earth metal or transition metal.

41. The method of claim 21, wherein additive component comprises a stoichiometric excess of the rare earth element of the precursor solution.

42. The method of claim 21, wherein the additive component comprises as stoichiometric  
20 excess of the alkaline earth metal of the precursor solution.

43. The method of claim 21, wherein the precursor solution comprises at least two rare earth elements.

44. The method of claim 21, wherein the precursor solution comprises at least two alkaline earth metals.

45. The method of claim 21, wherein the precursor solution comprises at least two transition metals.

5 46. The method of claim 21, wherein the additive component comprises a salt of a metal selected from the group consisting of cerium, zirconium, silver, aluminum, and magnesium.

47. The method of claim 39, wherein the nanoparticle dispersion is reactive with one or more elements of the precursor components of the precursor solution.

48. The method of claim 39, wherein the nanoparticle is selected from the group consisting  
10 of zirconium oxide, aluminum oxide,  $Y_2BuCuO_4$ ,  $Y_2Cu_2O_5$ , magnesium oxide,  $BaZrO_3$ , silver and ceria.

49. The method of claim 40, wherein the one or more metal salts of the additive component is reactive with one or more elements of the precursor components of the precursor solution.

50. The method of claim 39, wherein the nanoparticle is selected from the group consisting  
15 of zirconium oxide, aluminum oxide,  $Y_2BuCuO_4$ ,  $Y_2Cu_2O_5$ , magnesium oxide,  $BaZrO_3$ , silver and ceria.

51. A method for producing a superconductor film containing second phase nanoparticles comprising:

converting a precursor film to an oxide superconductor film, the precursor film  
20 comprising one or more rare earth elements, one or more alkaline earth metals and one or more transition metals, and an additive component, the additive component comprising one or more metals elements capable of forming a second phase nanoparticle, either alone or in combination



with one or more of the rare earth element, alkaline earth metal or transition metal of the precursor film,

wherein the oxide superconductor film is formed at a growth rate of 2 – 200 Å/sec, and wherein the oxide superconductor film contains one or more second phase nanoparticles located within a grain of the oxide superconductor that serve as a pinning center.

52. The method of claim 51, wherein the precursor film is converted to an oxide superconducting film at a growth rate of 5 – 200 Å/sec.

53. The method of claim 51, wherein the precursor film is converted to an oxide superconducting film at a growth rate of 10 – 200 Å/sec.

54. The method of claim 51, wherein the precursor film is converted to an oxide superconducting film at a growth rate of greater than 20 Å/sec.

55. The method of claim 51, wherein heating the intermediate film comprises heating at a temperature in the range of about 700°C to about 825°C in a flowing gas environment having a total pressure of about 0.1 Torr to about 760 Torr and containing about 0.09 Torr to about 50 Torr oxygen and about 0.01 Torr to about 150 Torr water vapor and an inert gas with a pressure of about 0 Torr to about 750 Torr.

56. The method of claim 51, wherein heating the intermediate film comprises heating at a temperature in the range of about 700°C to about 825°C in a flowing gas environment having a total pressure of about 0.15 Torr to about 5 Torr and containing about 0.1 Torr to about 1 Torr oxygen and about 0.05 Torr to about 4 Torr water vapor.

57. An article comprising:

a thin film on a substrate, wherein the thin film, which is deposited onto the substrate from a solution-based precursor, comprises a rare-earth/alkaline-earth-metal/transition-metal oxide superconductor and at least one second phase nanoparticle comprising a metal-containing compound located within a grain of the oxide superconductor, wherein the second phase nanoparticle serves as a pinning center.

58. The article of claim 57, wherein the second phase nanoparticle has a maximum dimension of 1-100 nm.

59. The article of claim 57, wherein the second phase nanoparticle is selected from the group consisting of zirconium oxide, aluminum oxide, BaCeO<sub>3</sub>, BaZrO<sub>3</sub>, silver, and magnesium oxide.

60. The article of claim 57, wherein the oxide superconductor comprises rare earth-barium-copper oxide.

61. The article of claim 57, wherein said substrate is a dielectric oxide of a material selected from the group consisting of cerium oxide, lanthanum aluminum oxide, lanthanum manganese oxide, strontium titanium oxide, magnesium oxide, neodymium gadolinium oxide, and a cerium oxide/yttria-stabilized zirconia.

62. The article of claim 57, wherein the second phase particulate has as least one dimension of less than about 50 nm.

63. The article of claim 57, wherein the second phase particulate has as least one dimension of less than about 20 nm

64. An article comprising:

a thin film on a substrate, wherein the thin film comprises a rare-earth/alkaline-earth-metal/transition-metal oxide superconductor and a secondary particulate phase comprising a metal-containing compound located within the grain of the oxide superconductor, wherein the  
5 second phase nanoparticle has a maximum dimension of 1-100 nm and serves as a pinning center, with the proviso that the metal-containing compound is not  $Y_2O_3$  or  $Y_2BaCuO_5$ .

65. The article of claim 64, wherein the secondary particulate phase is selected from the group consisting of zirconium oxide, aluminum oxide, silver, alkaline earth zirconates, and  $BaZrO_3$  magnesium oxide.

10 66. The article of claim 64, wherein the oxide superconductor comprises rare earth-barium-copper oxide.

67. The article of claim 64, wherein said substrate is a dielectric oxide of a material selected from the group consisting of cerium oxide, lanthanum aluminum oxide, lanthanum manganese oxide, strontium titanium oxide, magnesium oxide, neodymium gadolinium oxide, and a cerium  
15 oxide/yttria-stabilized zirconia.

68. The article of claim 64, wherein the second phase particulate has as least one dimension of less than about 50 nm.

69. The article of claim 64, wherein the second phase particulate has as least one dimension of less than about 20 nm